

Memorandum

10 September 2018

To: Radiation Physics Science Department
From: William S. Higgins
Subject: Revised Soil Equivalent for Selected Shielding Materials

In shielding assessments, quantity of shielding has been expressed in "equivalent feet of dirt." In many past assessments, soil typical of Fermilab's was stated to have a tenfold attenuation length or "tenth value layer" (TVL) of 2.8 feet. For materials other than soil, a scale factor has been applied. Iron was treated as 2.8 times more effective than an identical thickness of soil. Concrete was 1.1 times more effective; heavy concrete was 1.65 times more effective.

More recently, Diane Reitzner revisited these equivalents, calculating the scale factors for several materials with MARS. She established a new TVL for soil of 3.38 feet. [1] This value has been adopted for subsequent shielding assessments.

In another document [2] she calculated TVLs for iron, concrete, and dolomite shielding. Each of these is denser than soil; their TVLs imply a scale factor:

$$\text{Scale factor} = \text{TVL (soil)}/\text{TVL (material)}$$

Thus, the scale factor of concrete is (3.38 feet of soil)/(2.86 feet of concrete) or 1.18. The thickness of a concrete shield can be multiplied by 1.18 to determine its effectiveness in equivalent feet of dirt. Table 1 lists these scale factors for each material considered.

| <i>Material</i> | <i>Tenth-Value Layer, feet</i> | <i>Soil Equivalent Scale Factor</i> |
|-----------------------|--------------------------------|-------------------------------------|
| <i>Soil</i> | 3.38 ± 0.01 | 1 |
| <i>Iron</i> | 1.10 ± 0.13 | 3.07 |
| <i>Dolomite</i> | 2.32 ± 0.04 | 1.46 |
| <i>Concrete</i> | 2.86 ± 0.03 | 1.18 |
| <i>Heavy Concrete</i> | 1.91 ± 0.02 | 1.77 |
| <i>Sand</i> | 4.73 | 0.72 |

Table 1: Tenth-value layers, in feet, and scale factors for shielding materials.

In this table, I have added a line for heavy concrete, presuming that its TVL scales inversely with density from the TVL for concrete, and that heavy concrete has a density of 1.5 times the density of ordinary concrete.

I have also added a line for sand, a material of lower density than soil. [3]

Another common shielding material is polyethylene. Since its effectiveness varies considerably with particle energy, it should not be reduced to a single TVL. Reference [4] is a guide to polyethylene shielding.

References

1. S. D. Reitzner, "Update to the Generic Shielding Criteria," Fermilab TM-2550-ESH, 6 November 2012.
2. S. D. Reitzner, "MARS Star Density Results for Shielding Applications," Fermilab TM-2470, 28 July 2010.
3. Bill Higgins to Wayne Schmitt, "Sand As a Shielding Material and Its Tenth-Value Layer," 5 November 2015.
4. Bill Higgins to Mike Gerardi, "Polyethylene Shielding Effectiveness," 21 July 2010.

cc: W. Schmitt